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INCLUDING PRESTRESSED CONCRETE

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CONCRETE
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Volume LIII, No. 11. LONDON, NOVEMBER, 1958.

EDITORIAL NOTES

Technologists and Responsibility.

IN the past few months some very severe comments have been made on the results of the present methods of training scientists and technologists.

Professor H. L. Elvin, Director-designate of the Institute of Education of London University, has advised young people about to start a technical course at a university to avoid listening to lectures as much as possible unless the lecturer be a man of outstanding ability, and to take an interest in subjects other than that in which they are specialising in order that they may leave college " as men, not technologists ". He urged them not to work for more than five hours a day on their special subject, and to spend the rest of their time in studying other subjects in order to broaden their knowledge.

In a speech at St. Andrew's University, Lord Geddes, one of the leading men in the oil industry, said that technologists rarely reached the summit in industry—though there were outstanding exceptions—because the pattern of scientific education in Great Britain was one of specialisation in technical studies to the exclusion of all other learning. He urged the universities to consider a programme that would limit technical training in one subject to two years, followed by education in arts subjects. He claimed that in this country the training of scientists did not develop a critical faculty—without which a man cannot be a scientist or engineer. He mentioned one of the major problems of the nation, and of the aims of so many young people to-day, when he referred to " the complete security conferred nowadays by a scientific degree " compared with the greater competition that has to be faced in administration where a man's worth is assessed by his ability to develop a business and to introduce new ideas.

The chairman of Imperial Chemical Industries, Ltd., has stated that, because of the quality of scientists and technologists who applied for employment, his company has provided scholarships for " men who have a broad general outlook based on an arts background and who would be acceptable to a university for their achievements in subjects other than science, and who it was hoped would form the nucleus of really bright technical students ".

Dr. Percy Dunsheath, C.B.E., a director of W. T. Henley's Telegraph Works,

the Cambridge Instrument Company, and other industrial undertakings, and a Member of the London Electricity Board, has pointed to the need of realising the difference between technical training and education: "Industry", he said, "is looking more and more for technologists in positions of leadership and high administrative responsibility. In order that they may acquire the vision and the wide grasp of affairs which such positions call for they need a background of more general culture such as economics, languages, history, and philosophy."

An editorial article * in the Journal of the Engineers' Guild states that by excluding man from his studies the engineer excludes the greatest of all sources of power and therefore forgoes the right to exert leadership over his fellow men . . . that confining his knowledge to engineering only will incur the risk of "reducing engineering from the status of a profession to that of a craft".

Last year London University omitted English from its examinations, and became the only University in the country willing to enrol semi-literates as students. A Standing Committee of the University now reports its concern at the low standard of English of many students entering the University, and recommends that steps be taken to improve the academic education of entrants.

The Ministry of Education has stated that "Engineering students have been conditioned to concentrate narrowly on taking as many technological subjects in the shortest possible time in order to obtain the maximum exemption from professional examinations. This is undesirable", and recommends that students of technical subjects be instructed in clear thinking and precise expression.

The Civil Service Commissioners have expressed their concern that many candidates for engineering and technical posts "fell short of the standard of basic technical knowledge implied by the qualifications they held", and stated their experience that "many of those recently qualified seem to have retained a disturbingly small store of lasting knowledge, and this of a superficial character".

The National Institute of Adult Education has expressed the view that "possession of a General Certificate of Education does not amount to much".

The education authorities of six county boroughs recently issued a report on the quality of candidates for the General Certificate of Education. Before the year 1939 one candidate in three obtained passes in the English language, mathematics, another language, and a science in this examination when it was known as the School Certificate of Education. In 1957 the number of passes in these four subjects ranged from 3 per cent. to 17 per cent., while as few as 9 per cent. to 31 per cent. obtained passes in three subjects only.

Dr. T. R. Glover, when he was Public Orator at Cambridge University, asked "whether the scientific and technical training which is so largely displacing education may not be leaving the mind and imagination of the student unfitted for living in a world which is, after all, not chiefly concerned with technical and scientific pursuits".

Not long ago a reviewer in "The Listener" wrote of sub-scholars in their turn becoming university lecturers and producing sub-sub-scholars, and in a letter to "The Times" one of our oldest universities was described as "a place where young men complacently anticipate their inheritance of the world by means of a second-class honours degree".

These speakers and writers no doubt felt justified in using strong language

* Reprinted on page 409 of this number.

in order to emphasise the importance of a problem that is causing increasing concern to the Government, to educationists, and to employers. It is a problem that has been emphasised in our Editorial Notes for more than thirty years. These Notes have brought much correspondence from readers, ranging in tone from the professor of civil engineering who thought it " incredible that the editor of a reputable journal should write in this way ", and the doctor of philosophy (engineering) who wrote " I do not see what useful purpose your Editorial Notes serve. All I want are facts, " to the consulting engineer who wrote " Your Editorial Notes have distinguished your journal above all other technical publications. We have admired their good sense, their penetrating thought, and their masterly quality of English expression. Thank you for your constructive thinking and your healthy realism ", and the chief engineer of a railway who had them copied and circulated to the engineers in his organisation.

The main purpose in writing these articles has been to encourage engineers and scientists to explore beyond technical problems. Since pupilage ceased an engineer's most formative years are too often spent at a school where he learns little and which he leaves early, and at a technical institute or university where he may do little more than absorb mathematics, formulæ, codes, standards, and textbooks in which he expects to find the answers to all his problems. If he is to be a good engineer, and not only a computer of stresses and a copyist, his mind must range far beyond what he has been taught at a course of technology. A course of study undertaken for the sole purpose of passing an examination is likely to develop the memory rather than the power of reasoning.

The vituperation no less than the appreciation of readers has encouraged the publishers to issue a number of these essays in book form * in the hope that those who found them distasteful, and others with similar views, may be persuaded to believe that a " full " man is a more useful member of society and a happier man than one who is master of a technical subject only. In particular it is hoped that they will encourage young men trained in engineering to improve their general education, so that they may improve their chances of rising to responsible positions. It is a saddening experience to meet university graduates in engineering who are unashamed at their inability to spell simple and common words, to hear them say that it does not matter if they use words which have a meaning different from that intended so long as they themselves know what they mean, that they have no use for art and suchlike time-wasting pursuits, and generally to deride education in its true sense. It seems that the clock is being set back a hundred years to the period in the so-called industrial revolution when manual workers were encouraged to learn to read and to attend Mechanics' Institutes only so that they might be able to follow written instructions and be more productive, and when others were taught a smattering of science only because they would be more useful to their employers. Now, as then, the imparting of enough technical knowledge for a man to earn a living seems to be the sole aim of some of our technical colleges and of universities which used to be known as seats of learning. Education and technical training are very different things.

Many of the essays now published in book form are comments on the spoken or written word of engineers and scientists who have not troubled to develop an

* " Editorial Notes from 'Concrete and Constructional Engineering'." (London: Concrete Publications, Ltd. 96 pages. Price 7s. 6d.)

inquiring mind, and whose apparently profound statements are shown to be sometimes illogical and sometimes sheer nonsense. It is hoped that these essays will encourage engineers to say and write exactly what they mean, and to avoid the pitfalls that beset those whose education has not developed their power of reasoning. Most of the follies and false reasoning commented upon, sometimes uttered or written by men eminent in their profession, could have been avoided by a study of elementary logic, a refusal to be carried away by high-sounding phrases or the latest catchwords, and a realisation that the slick phrase or wisecrack seldom contains much truth. The arrogance, conceit, and self-satisfaction that often comes with the possession of a degree in a technical subject or membership of a professional society may be the result of an " inferiority complex " due to lack of general education, and can be a direct route to a cloud-cuckooland of absurd claims. It is hoped that this book will help young engineers to achieve that broader outlook and more mature judgment that some of our leading industrialists insist upon in men who are to rise to higher and more responsible posts, and to justify the claim so often made that scientists and engineers should take a leading part in directing the affairs of the nation.

The great need to-day is for technologists and scientists who have found time to do more than acquire knowledge of a technical subject only. Industries, whether nationalised or not, are crying aloud for such men to fill the top posts in their organisations. Few have the opportunity to become " full " men while they are at school or at a university. If they are to do more than compute stresses and assist in laboratories they must make an effort to provide for themselves the education that has been denied to them or which they have not troubled to acquire. When Francis Bacon wrote " Reading maketh the full man " he meant books which give the reader a wider mental outlook, a knowledge of men's triumphs and failings, and a sense of perspective. When we know, for example, that atomic energy was not produced until a thousand years after Lucretius expounded the atomic theory of the structure of matter and described the power that would be released if an atom were split, we may wonder what would be achieved to-day if such men were working in a modern laboratory or applying their tremendous powers of reasoning to the possibilities of the materials now available.

A feature of these essays are comments on some of the stupidities that have been written and spoken by engineers and scientists with illogical minds that result in loose thinking. It is hoped that they will not only be helpful in themselves but will lead to reading of the masterly and exciting works of the ancient philosophers, which are often deemed to be stodgy and high-brow merely because they are known as classics. Many men whose education has been neglected will be surprised to learn that the vast development in technology has not been accompanied by any progress in ethics and the power of reasoning for more than two thousand years. A list of recommended books is given; they were all written centuries ago but are as topical to-day as when they were written, for human nature has not changed and social and political problems in a civilised society are basically the same as ever. The book is as provocative as the foregoing notes, but it is hoped that both this article and the book are sufficiently constructive to encourage young technologists to improve their education so that they will qualify for the administrative posts that await them and no longer be subjected to such biting criticisms as those quoted at the beginning of this Note.

Determination of Bending Moments in Rigid Frames.

By A. BANNISTER, M.C., B.Sc., A.M.I.C.E.

THE purpose of this article is to describe the analysis of rigid frames subjected to vertical or lateral loading by means of a non-sway moment-distribution analysis and a correction for sway by a " no-shear " method.[1]

A common method of calculating the bending moments in a multiple-story multiple-bay rigid frame is first to distribute the fixing moments assuming that displacement of the joints is prevented by propping forces. The number of such forces required depends upon the number of degrees of freedom the frame possesses, and these forces may be determined from the moments (and possibly also from the loading) occurring at this stage. Arbitrary sway moments are then applied and distributed, the number of such distributions again depending upon the number of degrees of freedom. From these a series of sway forces, acting at the levels at which the propping forces are applied, can be determined and, if each distribution is multiplied by an appropriate factor, a set of simultaneous equations which include the sway forces and propping forces can be formed by adding the sway forces resulting from, and multiplied by the factor for, each distribution at one level to the propping force acting at that level. The solution of the equations will give the values of the factors, which are applied to their respective distributions ; the sum of all the modified sway distributions gives the sway correction and, when added to the non-sway distribution, the final moment at each joint. The method is laborious and the " no-shear " method can be used to give a more direct solution for the sway correction, since for equilibrium at any level the propping force must be neutralised by an equal and opposite sway force.

The no-shear method due to Mr. N. Naylor applies to single-bay multiple-story symmetrical frames. In this method the shear at any story is determined and halved to allow for the fact that each half of the symmetrical frame sustains half the load. The product of the story-shear and the story-height gives the sum of the equal moments induced at the top and bottom of the stanchion at this level ; this sum is constant even though the two moments may change as distribution occurs, since carry-over factors of -1 in the columns and zero in the beams are used. In computing the distribution-factors, the stiffnesses of the columns are assumed to be $\frac{I_c}{L_c}$ and of the beams $\frac{6I_b}{L_b}$, in which the suffixes c and b refer to columns and beams respectively. By means of these factors and stiffnesses, rotation of the joints and sway are assumed to occur simultaneously, whereas in the method previously mentioned the frame is assumed to be displaced laterally at the level of a story, arbitrary moments are assumed to be induced, and no further sway is assumed to occur during the ensuing distribution.

In recent articles by Dr. Lightfoot [2] and Mr. Thadani [3] methods have been developed for analysing rigid frames subjected to lateral loading, the former using an equivalent column and the latter a method based on Mr. Naylor's. In each case an exact result is obtained for a " multiple " frame. In such a frame (*Fig.* 1a) all the joints at the level of any beam rotate through the same angle

when the frame is loaded laterally, this property being due to the stiffness characteristics. The principle of "multiples" was developed by Dr. Kloucek,[4] who showed how some rigid frames can be designed in a similar manner to single-bay frames (*Figs.* 1b and 1c). Thus, if the moments in either of the frames in *Fig.* 1b are determined, those in the other can be derived and, by addition, the moments in the frame in *Fig.* 1a can be obtained. However, instead of using the frames in *Fig.* 1b and *Fig* 1c and adjusting the moments in accordance with the stiffnesses of the posts and beams, the frame shown in *Fig.* 2a can be used. This is done by adding all Mr. Naylor's "equivalent" frames together, the stiffness-ratios of the beams being multiplied by six to obtain the equivalent frames.

Fig. 2b shows Mr. Naylor's equivalent frame and *Fig.* 2c shows the equivalent frame as given by Dr. Lightfoot. In *Fig.* 2c the sum of the stiffnesses of the columns in each story and twelve times the sum of the stiffnesses of the beams at each level are evaluated, the full values of the loads being used. In all three cases the distribution factors are based on the stiffnesses shown; carry-over factors of -1 are adopted. In Dr. Lightfoot's method the distributed moments are shared in proportion either to the stiffnesses of the columns or the stiffnesses of the beams at any particular level, half of the shared beam-moment being applied at each end of the beam. The moments obtained from *Fig.* 2a are the required values and need no further reduction. The moments in the story are initially shared according to the stiffness-ratios of the columns.

Examples.

EXAMPLE 1.—Find the moments at the joints in the frame shown in *Fig.* 2a. The sum of the column-moments in each story is equal to the product of the horizontal shear in the story and the height of the story. Thus in the upper

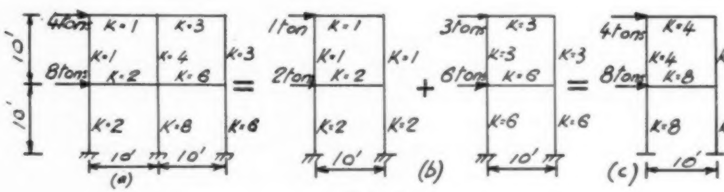


Fig. 1.

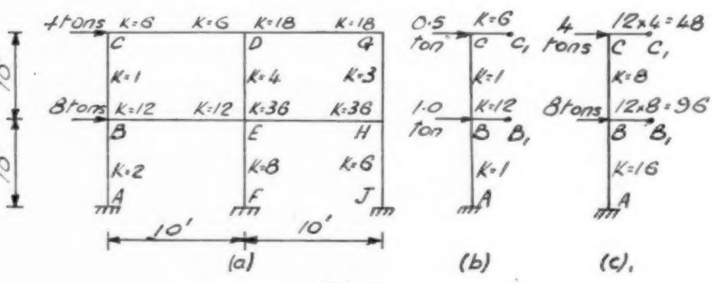
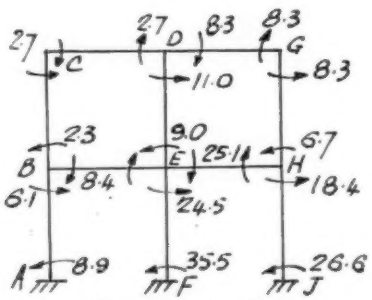


Fig. 2.

TABLE I.

		1/7	6/7	6/28	4/28	18/28		18/21	3/21	
		CB	CD	DC	DE	DG		GD	GH	
		−2.5			−10.0				−7.5	
Balance		+0.4	+2.1	+2.1	+1.4	+6.5		+6.5	+1.0	
Carry Over		−0.7			−2.7				−2.0	
Balance		+0.1	+0.6	+0.6	+0.4	+1.7		+1.7	+0.3	
Carry Over					−0.1				−0.1	
Balance						+0.1		+0.1		
Total		−2.7	+2.7	+2.7	−11.0	+8.3		+8.3	−8.3	
	2/15	1/15	12/15	12/60	4/60	8/60	36/60	36/45	3/45	6/45
	BA	BC	BE	EB	ED	EF	EH	HE	HG	HJ
	−7.5	−2.5			−10.0	−30.0			−7.5	−22.5
Balance	+1.3	+0.7	+8.0	+8.0	+2.7	+5.3	+24.0	+24.0	+2.0	+4.0
Carry Over		−0.4			−1.4				−1.0	
Balance	+0.1		+0.3	+0.3	+0.1	+0.2	+0.8	+0.8	+0.1	+0.1
Carry Over		−0.1			−0.4				−0.3	
Balance			+0.1	+0.1			+0.3	+0.3		
Total	−6.1	−2.3	+8.4	+8.4	−9.0	−24.5	+25.1	+25.1	−6.7	−18.4
	AB					FE				JH
	−7.5					−30.0				−22.5
Carry Over	−1.3					−5.3				−4.0
Carry Over	−0.1					−0.2				−0.1
Total	−8.9					−35.5				−26.6



Moments in tons-feet.

Fig. 3.

story the moments total $-4 \times 10 = -40$ tons-ft. and in the lower story $-(4+8) \times 10 = -120$ tons-ft. The negative sign indicates that anti-clockwise moments are produced.

These moments are applied in the ratios of 1 : 8, 4 : 8 and 3 : 8 in BC, DE, and GH respectively, and also in the ratios 2 : 16, 8 : 16 and 6 : 16 in AB, FE, and JH respectively, equally at each end of the members, and are entered in *Table* I. Thus at BC and CB the moments applied are

$$-40 \times \tfrac{1}{8} \times \tfrac{1}{2} = -2{\cdot}5 \text{ tons-ft.};$$

at FE and EF, $$-120 \times \frac{8}{16} \times \tfrac{1}{2} = -30 \text{ tons-ft.}$$

When the distribution-factors have been computed from the stiffness-factors shown in *Fig.* 2, a distribution by Mr. Naylor's method is made with carry-over moments in the columns but not in the beams. After each distribution equal moments occur at each end of any one beam, and after each carry-over the sum of the moments acting on the columns remains −40 tons-ft. or −120 tons-ft., depending upon the story considered. The final moments are obtained when no further carry-over is possible, and these are shown in *Fig.* 3. At the level of any beam little or no alteration is required to slide-rule settings when distributing the moments due to the "multiple" effect, but the distribution-factors must be in the form shown in the table and not simplified. This method is used in Example 2 and in the sway-correction in Example 3. In Example 3, when the columns are vertical, the table for the sway-correction moments is of the same form as that required for the non-sway distribution, but different distribution-factors are used.

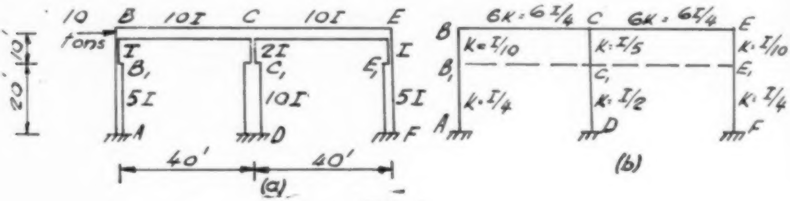


Fig. 4.

TABLE II.

	2/32	30/32	30/64	4/64	30/64		30/32	2/32
	BB_1	BC	CB	CC_1	CE		EC	EE_1
	−12.5			−25.0				−12.5
Balance	+0.8	+11.7	+11.7	+1.6	+11.7		+11.7	+0.8
Carry Over	−10.7			−21.4				−10.7
Balance	+0.6	+10.1	+10.1	+1.2	+10.1		+10.1	+0.6
Carry Over	−0.2			−0.4				−0.2
Balance		+0.2	+0.2		+0.2		+0.2	
Total	−22.0	+22.0	+22.0	−44.0	+22.0		+22.0	−22.0

	5/7	2/7	0	0	4/14	10/14	0	0	2/7	5/7
	B_1A	B_1B	B_1C_1	C_1B_1	C_1C	C_1D	C_1E_1	E_1C_1	E_1E	E_1F
	−25.0	−12.5			−25.0	−50.0			−12.5	−25.0
Balance	+26.8	+10.7	0	0	+21.4	+53.6	0	0	+10.7	+26.8
Carry Over		−0.8			−1.6				−0.8	
Balance	+0.6	+0.2	0	0	+0.4	+1.2	0	0	+0.2	+0.6
Carry Over		−0.6			−1.2				−0.6	
Balance	+0.5	+0.1	0	0	+0.3	+0.9	0	0	+0.1	+0.5
Total	+2.9	−2.9	0	0	−5.7	+5.7	0	0	−2.9	+2.9
	AB_1					DC_1				FE_1
	−25.0					−50.0				−25.0
Carry Over	−26.8					−53.6				−26.8
Carry Over	−0.6					−1.2				−0.6
Carry Over	−0.5					−0.9				−0.5
Total	−52.9					−105.7				−52.9

TABLE III.

3/4	1/4		1/12	9/12	2/12		2/24	18/24	4/24	4/16	12/16	
CB	CD		DC	DE	DG		GD	GH	GK	KG	KL	KN
									-12.0	+12.0		-20.0
							+1.0	+9.0	+2.0	+2.0	+6.0	
					+0.5			+2.5	+1.0	+1.0	+1.5	
			0	-0.4	-0.1		-0.3	-2.6	-0.6	-0.8	-1.9	
				-0.1	-0.1			-0.9	-0.3	-0.3	-0.7	
				+0.2			+0.1	+0.9	+0.2	+0.3	+0.7	
				+0.1				+0.3	+0.1	+0.1	+0.2	
				-0.1				-0.4			-0.3	
			0	-0.3	+0.3		+0.8	+8.8	-9.6	+4.5	+5.5	-20.0

4/9	3/9	2/9	2/27	12/27	9/27	4/27	4/54	24/54	18/54	8/54	8/36	12/36	16/36	
BA	BC	BE	EB	EF	ED	EH	HE	HJ	HG	HL	LH	LK	LM	LO
										-15.0	+15.0			-26.0
							+1.1	+6.7	+5.0	+2.2	+2.0	+3.0	+4.0	
						+0.5			+4.5	+1.0	+1.1	+3.0		
			0	-0.2	-0.2	-0.1	-0.4	-2.5	-1.8	-0.8	-0.9	-1.4	-1.8	
					-0.2	-0.2			-1.3	-0.4	-0.4	-0.9		
				+0.2	+0.2		+0.1	+0.8	+0.6	+0.2	+0.3	+0.4	+0.6	
					+0.1				+0.4	+0.1	+0.1	+0.3		
				-0.1				-0.3	-0.2			-0.2	-0.2	
			0	-0.1	-0.1	+0.2	+0.8	+4.7	+7.2	-12.7	+17.2	+4.2	+2.6	-26.0
AB				FE				JH					ML	
								+3.3					+2.0	
				-0.1				-1.2					-0.9	
				+0.1				+0.4					+0.3	
								-0.1					-0.1	
				0.0				+2.4					+1.3	

TABLE IV.

	3/9	6/9		6/27	9/27	12/27		12/54	18/54	24/54	24/36	12/36	0
	CB	CD		DC	DE	DG		GD	GH	GK	KG	KL	KN
	-0.9				-2.7				-5.4			-3.6	
Balance	+0.3	+0.6		+0.6	+0.9	+1.2		+1.2	+1.8	+2.4	+2.4	+1.2	
Carry Over	-0.2				-0.6				-1.2			-0.8	
Balance	+0.1	+0.1		+0.1	+0.2	+0.3		+0.3	+0.4	+0.5	+0.5	+0.3	
Carry Over					-0.1				-0.3			-0.2	
Balance						+0.1		+0.1		+0.2	+0.2		
Total	-0.7	+0.7		+0.7	-2.3	+1.6		+1.6	-4.7	+3.1	+3.1	-3.1	0

	4/19	3/19	12/19	12/57	12/57	9/57	24/57	24/114	24/114	18/114	48/114	48/76	12/76	16/76	0
	BA	BC	BE	EB	EF	ED	EH	HE	HJ	HG	HL	LH	LK	LM	LO
	-0.3	-0.9			-1.2	-2.7			-2.4	-5.4			-3.6	-1.6	
Balance	+0.3	+0.2	+0.8	+0.8	+0.8	+0.6	+1.6	+1.6	+1.6	+1.2	+3.3	+3.3	+0.8	+1.1	
Carry Over		-0.3				-0.9				-1.8			-1.2		
Balance	+0.1		+0.2	+0.2	+0.2	+0.1	+0.4	+0.4	+0.4	+0.3	+0.8	+0.8	+0.2	+0.2	
Carry Over		-0.1				-0.2				-0.4			-0.3		
Balance			+0.1	+0.1			+0.1	+0.1	+0.1		+0.2	+0.2		+0.1	
Total	+0.1	-1.1	+1.1	+1.1	-0.2	-3.1	+2.1	+2.1	-0.3	-6.1	+4.3	+4.3	-4.1	-0.2	0
	AB				FE				JH					ML	
	-0.3				-1.2				-2.4					-1.6	
Carry Over	-0.3				-0.8				-1.6					-1.1	
Carry Over	-0.1				-0.2				-0.4					-0.2	
Carry Over									-0.1					-0.1	
Total	-0.7				-2.2				-4.5					-3.0	

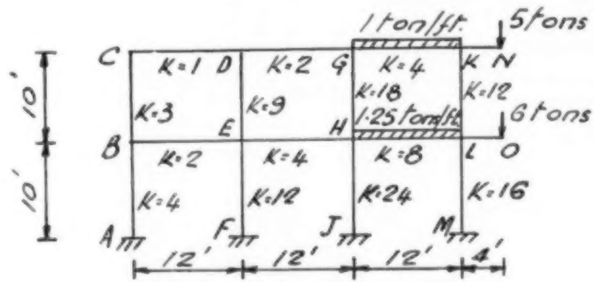


Fig. 5.

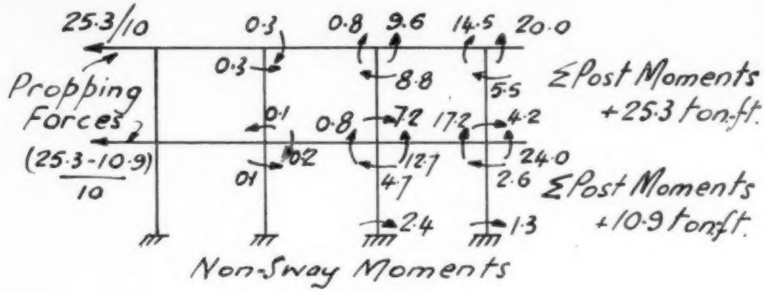


Fig. 6.

If required, the rotations of the joints could be obtained, for example, by the method of slope-deflection; it would be found that $\theta_C = \theta_D = \theta_G$ and $\theta_B = \theta_E = \theta_H$. The same relationship obtains between the frames shown in *Figs.* 1a, 1b, and 1c.

EXAMPLE 2.—The frame shown in *Fig.* 4a is a "multiple" frame with lateral loading at the level of the beam. In the analysis, a beam with zero stiffness is assumed to be inserted at the change of section of the columns; the points so joined have equal rotations and displacements. The stiffness-ratios of the columns are $\frac{5I}{20}$ and $\frac{I}{10}\left(\text{or } \frac{10I}{20} \text{ and } \frac{2I}{10}\right)$ respectively. The stiffnesses adopted in computing the distribution-factors are given in *Fig.* 4b. The moments shared in each story, above or below B_1, C_1, and E_1, are $-10 \times 10 = -100$ tons-ft. and $-10 \times 20 = -200$ tons-ft. No moment is distributed to the imaginary beam. The distribution is shown in *Table* II.

EXAMPLE 3.—In this example the three-bay, two-story, "multiple" frame in *Fig.* 5 is analysed in two stages. In the non-sway stage (*Table* III), the moments and the propping forces acting at each floor level are calculated and are then corrected in the second stage, in which moments totalling $-25{\cdot}3$ tons-ft. are applied in the upper story in proportion to the stiffnesses of the columns; in the lower story the moments total $-10{\cdot}9$ tons-ft. These are distributed in *Table* IV, the distribution-factors being based on six times the stiffness-ratios of the beams; carry-over factors of -1 are used in the columns. On adding the final moments of *Table* IV to those of *Table* III or *Fig.* 6 the required moments are obtained; they are shown in *Fig.* 7.

In the general case, when the frame is not a multiple, the use of an equivalent stiffness-ratio of $6K$ for the beams will give approximate sway-corrections, so that some indication of the final moments can be obtained to check the suitability of the sections chosen. As the properties of the frame depart from those of a multiple, so the reliability of the value $6K$ is reduced. Dr. Kloucek has suggested factors for use in general cases varying from about $5{\cdot}9K$ when the requirements of the principle of multiples are approximately fulfilled to about $5{\cdot}75K$ in the general case.

Dr. Lightfoot's method can be used for the accurate sway-analysis of general frames. Using the equivalent frame, approximate values for the moments are first obtained, and the final moments are determined by the method of successive

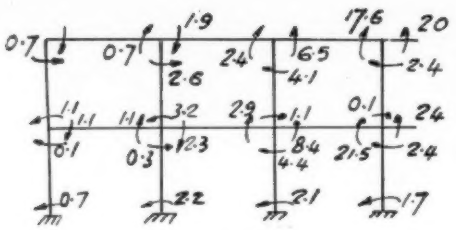


Fig. 7.

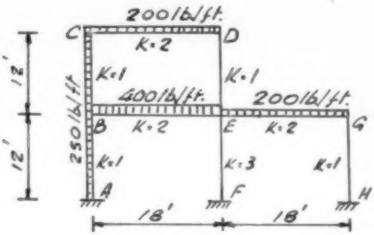


Fig. 8.

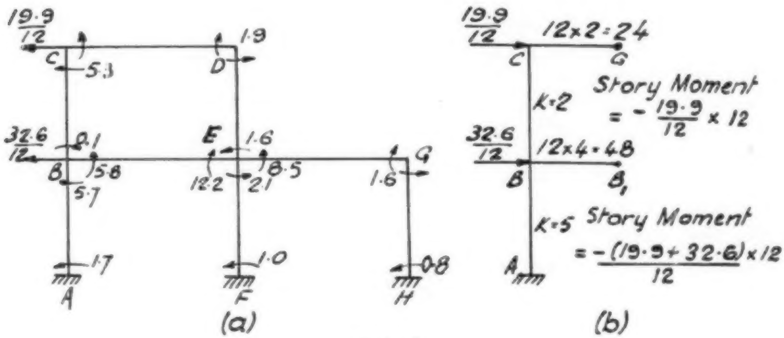


Fig. 9.

shear-corrections propounded by Dr. Grinter.[5] This method is used in the next example.

EXAMPLE 4.—Determine the moments at the joints of the frame shown in *Fig.* 8. The propping forces are evaluated from the non-sway moments shown in *Table* V and *Fig.* 9a and the lateral loading. At level CD the propping force is $1000 \times \left(\frac{5\cdot3 + 0\cdot1}{12} - \frac{1\cdot9 + 1\cdot6}{12} + \frac{250 \times 6}{1000}\right) = \frac{19{,}900}{12}$ lb. towards the left; at level BEG it is

$$1000 \times \left(\frac{5\cdot7 - 1\cdot7}{12} - \frac{2\cdot1 + 1\cdot0}{12} - \frac{1\cdot6 + 0\cdot8}{12} - \frac{1\cdot9}{12} + 3\cdot0\right) = \frac{32{,}500}{12} \text{ lb.}$$

towards the left (*Table* V).

Equal and opposite sway forces are now assumed to act at the same levels, and the equivalent frame in *Fig.* 9b is formed by multiplying by 12 the sum of the beam-stiffnesses at each level and adding all the column-stiffnesses at each story. A distribution by Mr. Naylor's method is made (*Table* VI) and the resulting moments shared in accordance with the stiffness-ratios of the members (*Fig.* 10a). The moments balance at C and D, and the out-of-balance moments at B, E, and G are −1200, −2400, and +3600 lb.-ft. respectively. These moments are balanced directly in the final (or shear) distribution indicated at the first balance, and then a carry-over is allowed. In this distribution the distribution-factors used in the non-sway distribution must be used. At the first shear-correction the moments at CB, BC, DE, and ED are totalled and corrections

TABLE V.

Moments tabulated in 1000 lb ft units

1/3	2/3	2/3	1/3
CB	CD	DC	DE
+3.0	-5.4	+5.4	
+0.8	+1.6	-3.6	-1.8
+1.3	-1.8	+48	-0.3
+0.2	+0.3	-0.3	-0.2
+5.3	-5.3	+1.9	-1.9

1/4	1/4	2/4	2/8	1/8	3/8	2/8	2/3	1/3
BA	BC	BE	EB	ED	EF	EG	GE	GH
+3.0	-3.0	-10.8	+10.8			-5.4	+5.4	
+2.7	+2.7	+5.4	-1.3	-0.7	-2.1	-1.3	-3.6	-1.8
	+0.4	-0.6	+2.7	-0.9		-1.8	-0.6	
		+0.2	0	0	0	0	+0.4	+0.2
+5.7	+0.1	-5.8	+12.2	-1.6	-2.1	-8.5	+1.6	-1.6
AB					FE			HG
-3.0					-1.0			-0.9
+1.3								+0.1
-1.7					-1.0			-0.8

TABLE VI.

Moments tabulated in 1000 lb. ft. units

		5/55	48/55	2/55	2/26	24/26
	AB	BA	BB_1	BC	CB	CC_1
	-26.3	-26.2		-10.0	-9.9	
Balance		+ 3.3	+31.6	+1.3	+0.8	+9.1
Carry Over	3.3			-0.8	-1.3	
Balance		+0.1	+0.7		+0.1	+1.2
Carry Over	0.1			-0.1		
Balance			+0.1			
Total	-29.7	-22.8	+32.4	-9.6	-10.3	+10.3

TABLE VII.

Moments tabulated in 1000 lb ft units

	1/3	2/3	2/3	1/3
	CB	CD	DC	DE
Balance	0	0	0	0
Carry Over	+0.1			+0.1
Shear Corr.n	-0.2			-0.2
Balance		+0.1	+0.1	
Total	-0.1	+0.1	+0.1	-0.1

	1/4	1/4	2/4	2/8	1/8	3/8	2/8	2/3	1/3
	BA	BC	BE	EB	ED	EF	EG	GE	GH
Balance	+0.3	+0.3	+0.6	+0.6	+0.3	+0.9	+0.6	-2.4	-1.2
Carry Over			+0.3	+0.3			-1.2	+0.3	
Shear Corr.n	0	-0.2			-0.2	+0.1			0
Balance			-0.1	+0.3	+0.1	+0.3	+0.3	-0.2	-0.1
Total	+0.3	+0.1	+0.8	+1.2	+0.2	+1.3	-0.3	-2.3	-1.3
	AB					FE			HG
Carry Over	+0.1					+0.4			-0.6
Shear Corr.n	0					0			0
Carry Over						+0.1			
Total	+0.1					+0.5			-0.6

applied in accordance with the stiffnesses of the members to reduce their sum (+0·8) to zero, thereby keeping their total in the final sway condition equal to −19,900 lb.-ft. Similarly, in the lower story the sum of the moments at BA, AB, EF, FE, GH, and HG (−0·1) is reduced to zero. The sum of the column moments, at any level, after the first balance and carry-over, is amended by the shear-correction to the values originally obtained from the distribution for the equivalent frame, namely −19,900 lb.-ft. and −52,500 lb.-ft., although the latter figure is slightly disturbed by the second balance (*Table* VII).

In this example the final stage in the table for shear-correction is to make a second balance but if, after this balance and a further carry-over, it is found that the sum of the column moments differs greatly from zero, a second shear-correction to obtain that value in each story would be needed and a third balance would be made. These moments are added to those in *Fig.* 10a to obtain the sway-correction moments given in *Fig.* 10b, which in turn are added to the non-sway moments in *Fig.* 9a to obtain the final moments shown in *Fig.* 11.

If only lateral loads act on the frame, the non-sway distribution could be omitted. The equations of equilibrium for the applied load would be found, connecting the sum of the column moments in each story with the moment due to the applied load (−18,000 lb.-ft. and −54,000 lb.-ft. in the upper and lower stories respectively). These moments are applied to the "equivalent" frame and distributed. In the shear-correction, the fixed-end moments for the lateral loading on AB and BC are combined with the moments obtained from the distribution for the equivalent frame, the whole being then balanced.

If the sway-correction moments are assessed assuming the stiffness-ratios of the beams to be multiplied by six, and using one sway distribution only (as

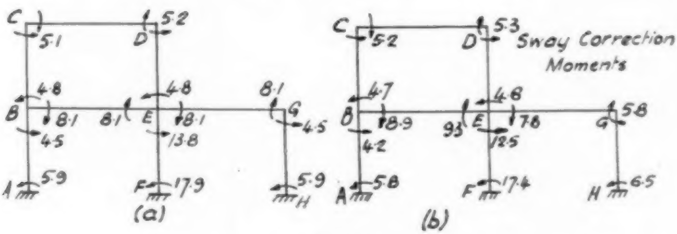


Fig. 10.

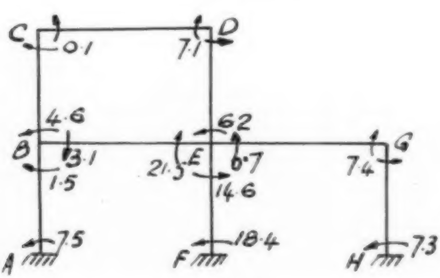


Fig. 11.

in Example 3), reasonable agreement with the accurate values are obtained at most of the joints. The biggest divergence occurs at joint GH, where the error is about 20 per cent.

The writer is indebted to the Governors and Principal of the Royal Technical College, Salford, for facilities given during the preparation of this article.

(1) Naylor, N. Side Sway in Symmetrical Building Frames. "Structural Engineer." April, 1950.

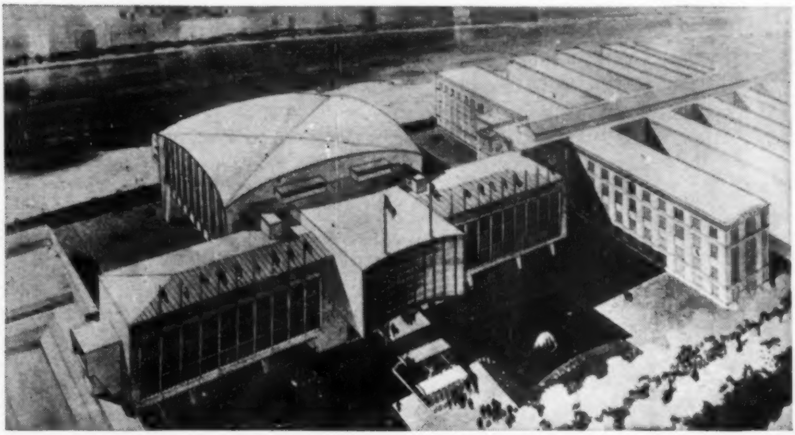
(2) Lightfoot, E. The Analysis for Wind Loading of Rigid-Jointed Multi-story Building Frames. "Civil Engineering and Public Works Review", Vol. 51, No. 601, July, 1956, and August, 1956.

(3) Thadani, B. N. The Exact Analysis of Multi-storeyed Structures subjected to Wind Loads. "Indian Concrete Journal", Vol. 30, No. 3, March, 1956.

(4) Kloucek, C. V. "Distribution of Deformation." Prague, 1949. Chapman & Hall, London, 1958.

(5) Grinter, L. E. "Theory of Modern Steel Structures" (Vol. 2). Macmillan, 1937. (Revised 1949.)

Congress Hall at Lyons.



To mark the 2000th anniversary of the founding of the city of Lyons, an International Congress Building is being erected. The structure will have three stories, and will comprise offices with an area of 1550 square metres and a frontage of 100 metres; a hall, with seats for 1450 people, a floor area of 2225 square metres, and a roof in the form of two hyperboloids which connect at right angles; a basement with space for 500 cars; a cinema; and other accommodation. The whole of the structure will be in reinforced concrete. The architects are MM. Salagnac. The photograph is of the architect's drawing.

A Prestressed Bridge at Manchester.

A RAILWAY bridge which will replace two existing bridges at Stockport Road, Manchester, is now nearing completion. It will have a span of 122 ft. and will support four railway tracks. Each track will rest on a hollow girder consisting of precast units prestressed together by means of post-tensioned cables; a cross section of the bridge is shown in *Fig.* 1.

Each girder has a structural depth of 7 ft. 6 in., and comprises sixteen precast units the weights of which vary from 30 to 35 tons. They are joined by transverse slabs cast in place, and are prestressed by sixteen Magnel-Blaton cables each containing 72 wires of 0·276 in. diameter, producing a total prestressing force of 3600 tons. The span is 107 ft. between the inner bearings and 139 ft. between the outer bearings. The four bearings for each beam are each placed under a stiffener, and because of the skew of the bridge (about 55 deg.) they are staggered with respect to the centre-line. In consequence there is a considerable uplift at the outer bearings, and the loads at the inner bearings are thereby increased. The upward forces are slightly reduced by torsion, but the rigidity of the section is such that the reduction is only about 10 per cent. It was not practicable to provide large forces acting downwardly at the outer bearings, and the levels of the bearings are therefore so adjusted

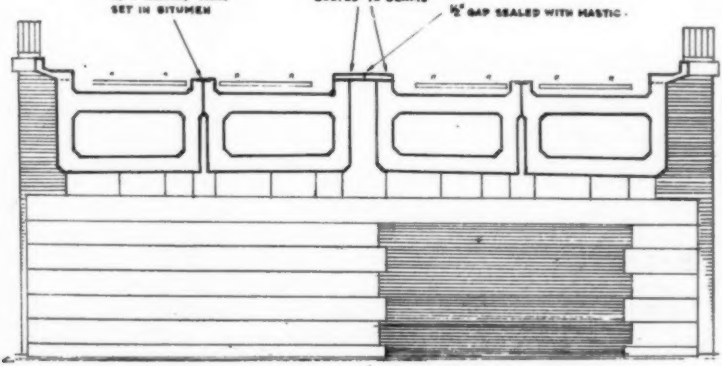


Fig. 1.—Section through Bridge.

Fig. 2.—Precast Parts Assembled before Concreting the Transverse Slabs.

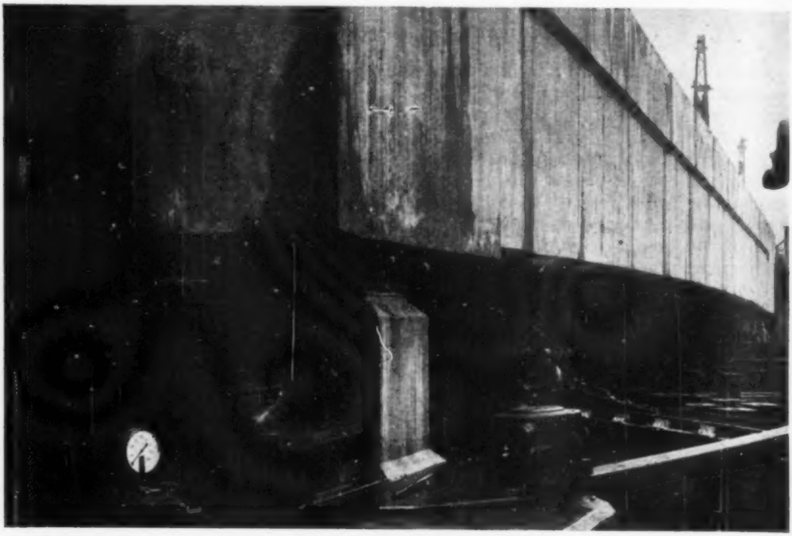


Fig. 3.—Beam before Lowering.

that nearly all the dead load (about 670 tons) is supported on the outer bearings. This initial load is therefore available to resist the upward live load of 350 tons. When the girder is fully loaded the total load on the inner bearings is 530 tons. The bearings consist of alternate layers of rubber and steel. Their deflections, and the effects of possible errors in level, were allowed for in the calculations.

The precast units for each beam were in turn erected on staging built alongside the existing bridges (*Fig.* 2). The slabs between the hollow-girder units were cast and the cables placed and tensioned. The beam was then lowered by means of jacks (*Fig.* 3) and rolled on to temporary reinforced concrete columns. At this stage the differences in level of the inner and outer bearings were checked while the whole load rested on the outer bearings, and packings in the bearings on the abutments were adjusted. The existing bridges were replaced by temporary beams which were removed to allow the concrete beams to be rolled into position.

Mr. J. Taylor Thompson is the Chief Civil Engineer of the London Midland region of British Railways. The main contractors are Messrs. Leonard Fairclough, Ltd.; Stressed Concrete Design, Ltd., prepared the drawings and calculations for the beams, and Anglian Building Products, Ltd., made the precast units.

Aggregates in Denmark.

THE Committee on Alkali Reactions in Concrete of the Danish National Institute of Building Research and the Academy of Technical Sciences has issued a report on the properties of flints and cherts occurring in Denmark. The report is in the Danish language, and has a long summary in the English language. Copies may be had from the Committee at Borgergade 20, Copenhagen.

Reaction of Concrete to Alkali.

FURTHER work at the Building Research Station has confirmed the conclusions reached previously that normal British aggregates when used as whole aggregates are not expansively reactive even with high-alkali cements at normal temperatures.

A Stand at a Bull-Ring in Colombia.

A MODEL of a stand for a bull-ring which has recently been built at Cali, Colombia, is shown in *Fig.* 1, and the completed structure is shown in *Fig.* 2. It has an external diameter of 312 ft. and a height above ground of 48 ft.

The stand can accommodate 18,000 people. There are fifteen entrances, seven of which are approached from the main gates and eight from a suspended walkway. The structure comprises twenty-four cantilevers which rest on two foundation rings (*Fig.* 3) and overhang the outer ring by about 60 ft. The treads of the terraces are 2½ in. thick and the risers 4 in. thick. Thirty-four peripheral prestressing cables, each with six or ten wires of 0·1 in. diameter (*Fig.* 3) pass through the cantilevers. The cylinder strength of the concrete was 4500 lb. per square inch at twenty-eight days. Most of the shuttering was of plywood.

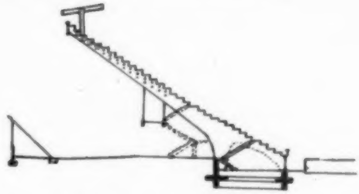


Fig. 3.—Cross Section.

Construction was started in January 1957 and the ring was opened in December the same year. The cost at that stage was 200,000 U.S. dollars (£71,000); it is expected to be completed this year at a total cost of 300,000 dollars (£106,500).

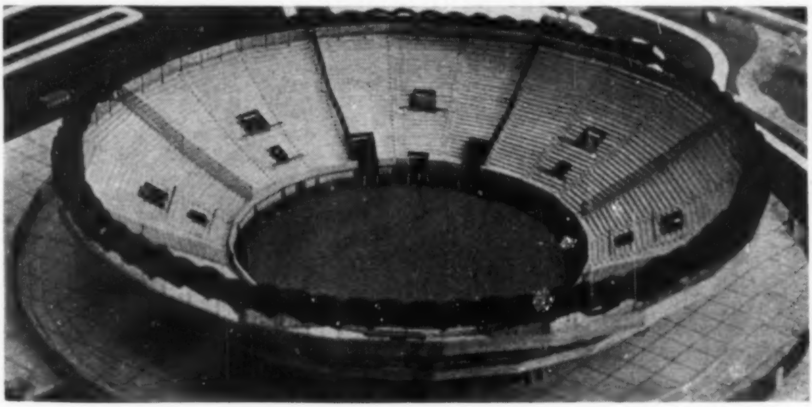


Fig. 1.—Photograph of a Model.

Fig. 2.—View of Completed Structure.

Fig. 4.—Detail of Underside of Terraces.

The architects were Srs. Julian Guerrero and Jaime Camacho, the structural engineers were Srs. Guillermo Gonzalez and Carlos Hernandez, the prestressed concrete was designed by Sr. Domenico Parma, and the contractors were Srs. Gino Faccio and Francisco J. Villaquiran, all of Colombia.

A New Type of Prestressed Floor Beam.

In *Fig.* 1 is shown a floor comprising prestressed beams made with precast hollow blocks and pre-tensioned steel and concrete ribs cast in place between the beams. A structural topping 1 in. thick may be added if desired.

The blocks are machine-made, and have a compressive strength of between 3000 lb. and 4000 lb. per square inch. Two grooves at the bottom each accommodates two prestressing wires, and in a groove at the top a single wire (which may be tensioned) is placed. The blocks to form a beam are assembled on a prestressing bed, and the wires, which may be 0·2 in. or 0·276 in. in diameter, are placed in position and tensioned to 150,000 lb. per square inch. Cement mortar, containing a plasticiser and expanding agent, is placed in the grooves, thereby embedding the wires and filling the adjacent portions of the joints. The prestress is applied to the beam when the strength of the mortar is 5000 lb. per square inch.

The blocks are fully matured before they are used, and uniformity of deflection is thereby obtained. Other advantages are stated to include economy of production and erection, the long spans (up to 30 ft.) which can be obtained, and good fire-resistant and sound-insulating properties. The beams are made by Anglian Building Products, Ltd., who are the proprietors of the system.

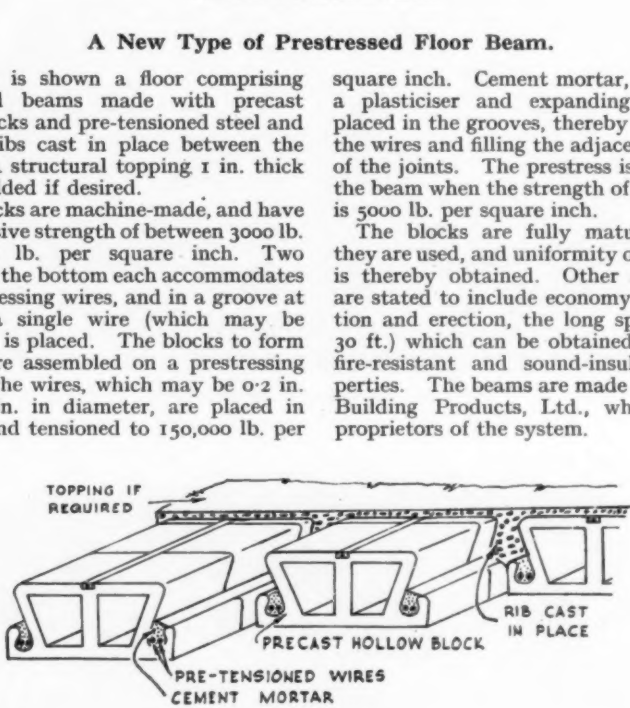


Fig. 1.

A Graphical Method for the Design of Prestressed Beams.

By E. W. BENNETT, M.Sc., A.M.I.C.E.

FORMULÆ for the minimum section moduli of a prestressed concrete beam have been given by the late Professor G. Magnel [1] and by the writer,[2] together with graphs for dimensioning sections to suit predetermined section moduli. The method now described applies when the area, centroid, and radius of gyration of the section are known and it is required to establish the magnitude and position of a suitable prestressing force. The method has the advantages that the need for a number of formulæ, each adapted to a particular type of problem, is avoided, and that it is based on the stress-distribution diagrams so that the effect of changes in the prestressing force is easily envisaged and the design is carried out in conjunction with the selection of the cross section.

The Basic Construction.

Let A be the area of the section, e_1 the distance of the centroid from the bottom, r the radius of gyration, and P the prestressing force acting at a distance e_s below the centroid (*Fig.* 1). To construct the diagram of the distribution of the prestress draw AB representing the depth of the section ; G represents the position of the centroid and S the position of the prestressing force. Draw GC to represent $\frac{P}{A}$ to a suitable scale of stress and GQ to represent r to the linear scale. Obtain the point O on AB (produced if necessary) such that angle SQO is 90 deg. Then O and C are points on the stress-distribution line DOCF.

PROOF.—Since Q lies on the circumference of a semicircle of diameter OS,

$$\mathrm{OG.GS} = \mathrm{QG}^2. \quad \text{Therefore } \mathrm{OG} = \frac{\mathrm{QG}^2}{\mathrm{GS}} = \frac{r^2}{e_s}, \quad \text{and} \quad \mathrm{OB} = \mathrm{OG} + \mathrm{GB} = \frac{r^2}{e_s} + e_1.$$

Also, by similar triangles,

$$\mathrm{BF} = \mathrm{GC}.\frac{\mathrm{OB}}{\mathrm{OG}} = \frac{P}{A}\left(\frac{r^2}{e_s} + e_1\right)\frac{e_s}{r^2} = \frac{P}{A}\left(1 + \frac{e_1 e_s}{r^2}\right).$$

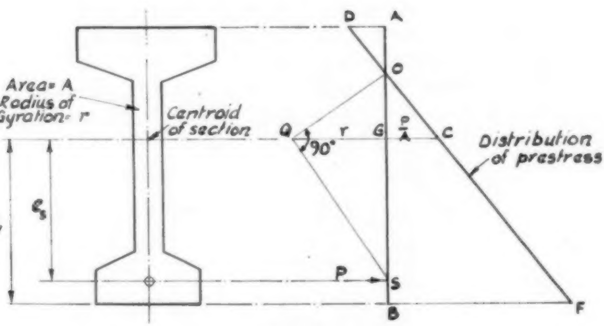


Fig. 1.

which is the stress in the concrete at the bottom of the beam. Similarly AD may be shown to be equal to the stress at the top.

The construction may also be used to obtain the magnitude and position of the prestressing force for a given distribution of prestress. When the tensioned wires are in two groups at known levels in a beam, for example in the top and bottom flanges, a further simple construction enables the number of wires in each group to be obtained, as in the following example.

Example 1.—The dimensions of the cross section of a beam are given in *Fig.* 2. If compressive prestresses of 1800 lb. per square inch at the bottom

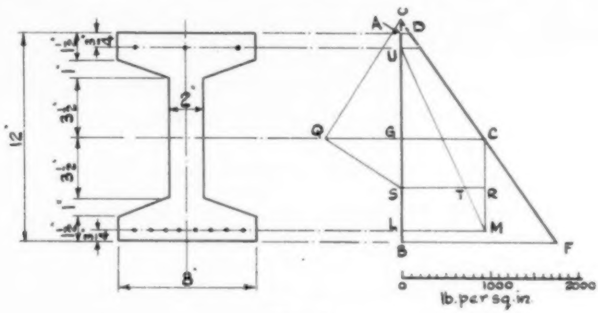


Fig. 2.

and 100 lb. per square inch at the top are required, find the number of 0·2-in. wires in each flange, assuming the force in each wire to be 4400 lb. and the distance of the wires from the top or bottom of the beam $\frac{3}{4}$ in.

The construction is carried out in the reverse order to that given previously; FD is first drawn to intersect BA produced at O, and the right-angled triangle OQS is completed to obtain S, the point of application of the resultant prestressing force. The magnitude of the prestressing force is given by the stress (represented by GC) multiplied by the area; thus, from *Fig.* 2, $P = 950 \times 48 = 45{,}600$ lb.

Lines perpendicular to AB are drawn through U and L to represent the levels of the two rows of wires. Line CM is drawn parallel to AB to intersect the line through L at M, and UM is drawn. Line STR is drawn through S, perpendicular to AB and intersecting UM and CM at T and R. Then the total force in the lower group of wires is the product of ST and the area of the section, and in the upper group is the product of TR and the area.

PROOF.—Let P' be the force in the lower group of wires, so that the force in the upper group is $P - P'$. Calculating moments about the centroid of the section,

$$P.\mathrm{SG} = P'.\mathrm{LG} - (P - P')\mathrm{UG},$$

and therefore

$$P' = \frac{P(\mathrm{SG} + \mathrm{UG})}{\mathrm{LG} + \mathrm{UG}} = P.\frac{\mathrm{SU}}{\mathrm{LU}}.$$

By similar triangles,

$$\mathrm{ST} = \mathrm{LM}.\frac{\mathrm{SU}}{\mathrm{LU}} = \mathrm{GC}.\frac{\mathrm{SU}}{\mathrm{LU}} = \frac{P}{A}.\frac{\mathrm{SU}}{\mathrm{LU}}.$$

Therefore $\quad ST = \frac{P'}{A}$ and $TR = \frac{P - P'}{A}$.

From *Fig.* 2, $P' = 34{,}800$ lb., so that $P - P' = 10{,}800$ lb. Eight wires are therefore required in the bottom flange ($P' = 35{,}200$ lb.) and three in the top flange ($P - P' = 13{,}200$ lb.).

Limits of the Prestress.

The size of the concrete section is generally greater than the theoretical minimum. This allows some latitude in the selection of the magnitude and position of the prestressing force, which must be such that the stresses in the concrete are less than the permissible stresses at two critical stages, namely, when the maximum prestressing force (immediately after prestressing) is combined with the minimum loading, and the minimum prestressing force (after all losses) with the maximum loading.

The limiting distributions of stress in the concrete are shown in *Fig.* 3 (a), in which the greatest and least compressive stresses with the minimum moment $M_{min.}$ are f_{ct} and $f_{min.\,t}$, and the greatest and least compressive stresses with the maximum working moment M_w are f_{cw} and $f_{min.\,w}$. The bending stress at the bottom, due to the minimum moment, is $\frac{M_{min.}}{Z_1}$ and at the top, due to the maximum moment, is $\frac{M_w}{Z_2}$, in which Z_1 and Z_2 are the respective section moduli. The upper boundary of the distribution of prestress may therefore be fixed as in *Fig.* 3 (a). When, however, $\frac{M_w}{Z_2}$ exceeds f_{cw}, so that the upper limit of the prestress at the top is negative (tensile), the greatest compressive stress at the

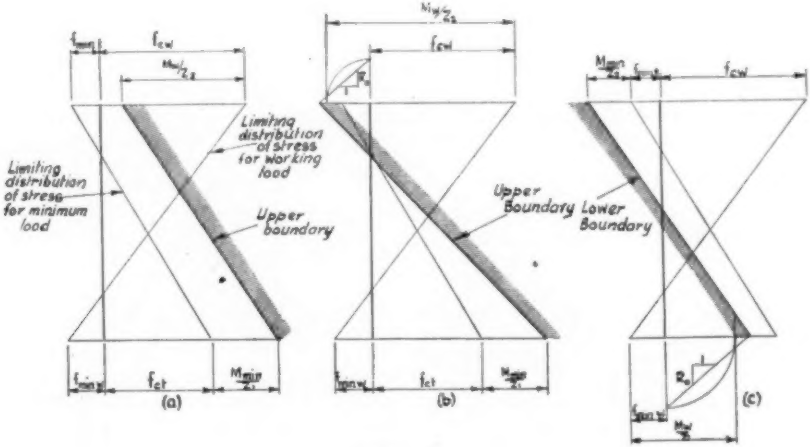


Fig. 3.

top occurs when the prestressing force is reduced to its minimum value. The negative prestress at the top must therefore be increased in the ratio $\frac{1}{R_0}$ of the maximum to the minimum prestress, which may be done by calculation or by the construction illustrated in *Fig.* 3 (b).

The lower boundary of the distribution of prestress is fixed by a similar method, as shown in *Fig.* 3 (c). Any distribution of prestress between the upper and lower boundaries will satisfy the conditions of stress, and the basic construction may be used to find the most suitable arrangement of the prestressing force.

Example 2.—The maximum bending moment at the section of the beam shown in *Fig.* 4 is 1,200,000 in.-lb. and the minimum moment is 350,000 in.-lb. The permissible stresses and ratio of losses are $f_{ct} = 2000$ lb. per square inch, $f_{cw} = 2400$ lb. per square inch, $f_{min.\,t} = 0$, $f_{min.\,w} = -300$ lb. per square inch, and $R_0 = 0{\cdot}85$. If the cable is to be $2\frac{1}{2}$ in. above the bottom, find the least value of the prestressing force.

The properties of the concrete section are $A = 114$ sq. in., $e_1 = 10{\cdot}30$ in., $r = 6{\cdot}82$ in., $Z_1 = 513$ in.^{3}, and $Z_2 = 545$ in.^{3} Using these and the foregoing data the boundaries of the prestress distribution diagram are constructed as described previously, and are shown in *Fig.* 4. By drawing GQ equal to the radius of gyration at the level of the centroidal axis, and completing the right-angled triangle SQO, the point O is obtained at which the prestress in the concrete is zero.

The least value of GC occurs when the prestress at the bottom, BF, touches the lower boundary. From the diagram GC is 878 lb. per square inch, and the least prestressing force is $878 \times 114 = 100{,}000$ lb.

Example 3.—*Fig.* 5 shows the section of a beam prestressed by two cables of sixteen 0·276-in. wires and one of forty wires, with a maximum force of 8500 lb. in each wire. If the prestress is to be varied along the beam by bending up the cables, find the upper and lower limits of the resultant prestressing force at a section where the maximum moment is 12,000,000 in.-lb. and the minimum moment 6,000,000 in.-lb. The permissible stresses and ratio of losses are

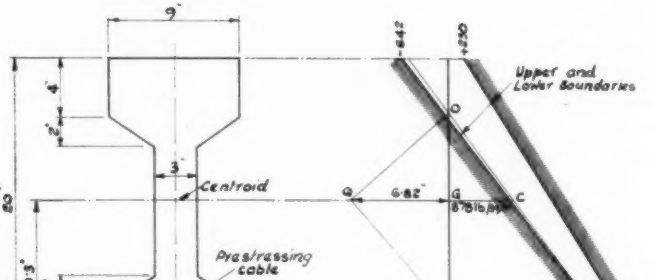


Fig. 4.

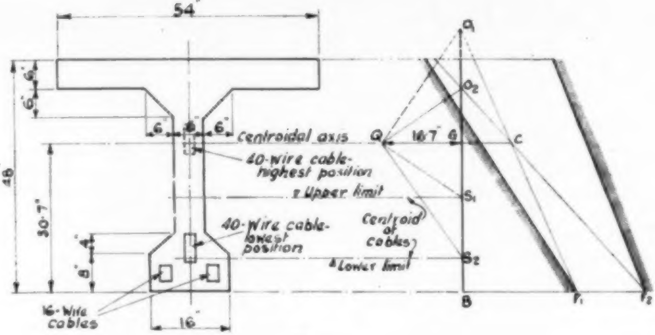


Fig. 5.

$f_{ct} = 2200$ lb. per square inch, $f_{cw} = 2400$ lb. per square inch, $f_{min.\ t} = -100$ lb. per square inch, $f_{min.\ w} = -200$ lb. per square inch, and $R_0 = 0{\cdot}85$.

The properties of the concrete section are $A = 712$ sq. in., $e_1 = 30{\cdot}7$ in., $r = 16{\cdot}7$ in., $Z_1 = 6460$ in.^{3}, and $Z_2 = 11{,}450$ in.^{3}

The upper and lower boundaries of the prestress distribution diagram are first constructed and GQ marked off to represent 16·7 in. The average stress GC is $\dfrac{72 \times 8500}{712} = 860$ lb. per square inch. The upper and lower limits of the line of action of the prestressing force will correspond to the prestress distribution diagrams for the least and greatest eccentricities of force that can be drawn within the boundaries. From *Fig.* 5, these are the lines F_1C and F_2C, touching the lower and upper limits at the bottom of the beam. The construction is completed to give the upper and lower limits, S_1 and S_2, of the position of the prestressing force; $BS_1 = 19{\cdot}2$ in. and $BS_2 = 6{\cdot}8$ in.

It would be possible to maintain the two cables of 16 wires at a constant distance of 4·2 in. from the bottom of the beam, and to calculate the position of the cable of 40 wires. By calculating moments, or by using the construction described in Example 1, the upper and lower limits of the centre of this cable are found to be 31·2 in. and 8·9 in. from the bottom of the beam, and the exact position may be chosen with regard to such other considerations as the resistance to shearing of the vertical component of the prestressing force, or the need to avoid excessive curvature of the cable.

(1) G. Magnel. "Prestressed Concrete." Concrete Publications, Ltd., London.
(2) See this journal for May, 1952.

Cost of Tall Steel and Reinforced Concrete Flats.

In its annual report for the year 1957 ("Building Research, 1957." H.M.S.O. Price 5*s*. 6*d*.) the Building Research Board of the Department of Scientific and Industrial Research states that alternative designs, with frames of steel and reinforced concrete, were prepared for a block of flats and a block of maisonettes. In both cases the reinforced concrete frame was 30 per cent. cheaper than the steel frame, representing a saving of 5 per cent. to 7 per cent. of the total cost of the finished buildings.

A Tall Reinforced Concrete Chimney.

THE illustrations show a reinforced concrete chimney 550 ft. high recently built at the works of the St. Lawrence Cement Company at Clarkson, Ontario, Canada. The chimney consists of two completely separate shafts, namely an inner brick shaft of 25 ft. 8 in. diameter at the bottom and 14 ft. 5 in. diameter at the top and varying in thickness from 26 in. to 8½ in., and an outer reinforced concrete shaft 37 ft. in diameter at the bottom and 23 ft. 6 in. diameter at the top and varying in thickness from 1 ft. 11 in. to 7 in. The distance between the two shafts is 3 ft. 9 in., and in this space a helical staircase is provided to enable inspection of the brick lining and the navigation lights. The concrete shaft is designed to resist the pressure of winds up to 170 miles an hour, and the purpose of the brick shaft is to prevent the gases from coming into contact with the concrete. The temperature of the gases entering the chimney is 600 deg. Fahr. High-alumina cement, made in England by the Lafarge Aluminous Cement Co., Ltd., was used in the mortar for setting the brick lining due to its immunity to the acids and sulphates in the gases and to its refractory properties. The chimney was designed and built by the Canadian Kellogg Company. *Figs.* 2 and 3 are on page 405.

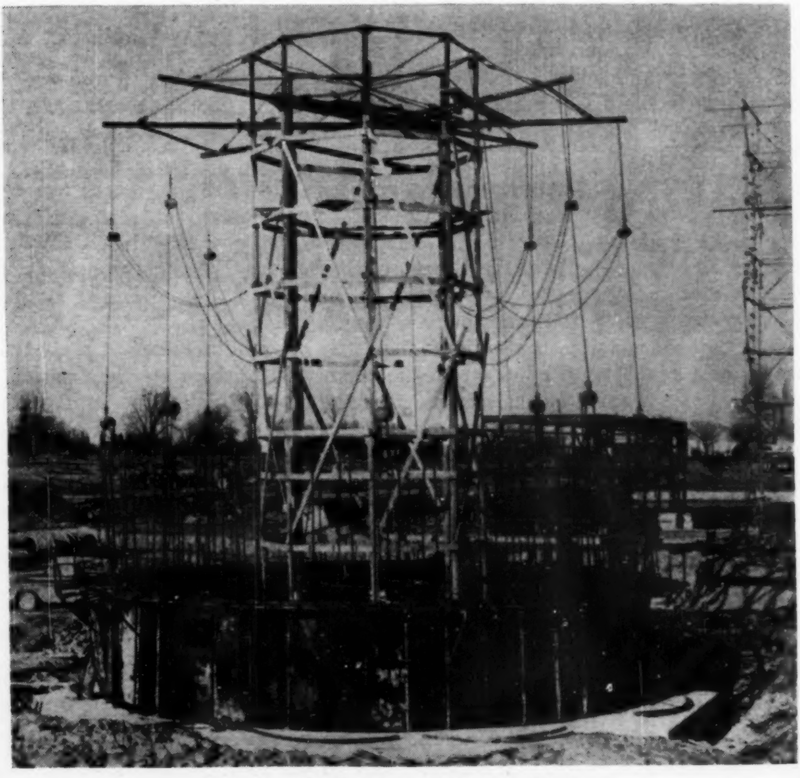


Fig. 1.—Staging and Climbing Shutter.

Fig. 2.—The Completed Chimney.

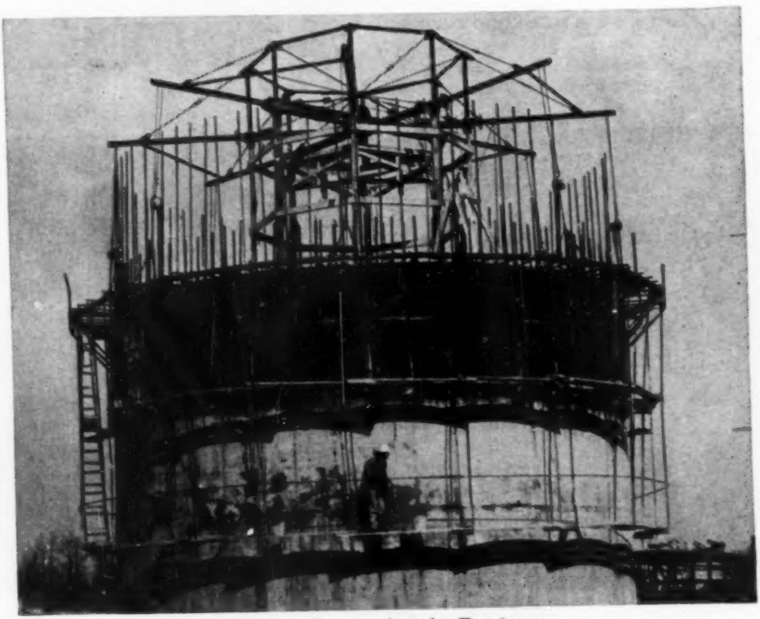


Fig. 3.—Concreting in Progress.

A Synagogue in Jerusalem.

AN UNUSUAL DOME.

THE synagogue described has the shape shown in *Figs.* 1 and 4, and is supported by eight elliptical arches; inside the building there is a platform about 59 ft. in diameter, supported on eight circular columns with a pitch circle of 36 ft. diameter, and a helical staircase (*Fig.* 2) leading from the floor to the platform. There are no internal partitions.

The plan is shown in *Fig.* 4. The structure is formed by arcs with radii of about 74 ft. and 18 ft., the resulting shape being intermediate between a square and a circle. There is no connection between the dome and the platform, the space between them being about 2 ft. 8 in. The space between the platform and the floor is glazed (*Fig.* 6).

The dome is designed to support its own weight together with a snow load of 15 lb. per square foot, a horizontal or vertical wind load of 30 lb. per square foot, an earthquake load acting horizontally equal to 10 per cent. of the weight of the dome, and the effects of temperatures from 0 deg. C. to 38 deg. C. The permissible stresses were 1000 lb. per square inch compression in the concrete and 25,600 lb. per square inch tension in the steel. The cement content of the concrete is 500 lb. per cubic yard, and the minimum cube strength at 28 days was specified to be 4000 lb. per square inch.

The dome was designed by the method of Professor Dischinger. By using Dr.

Fig. 2.

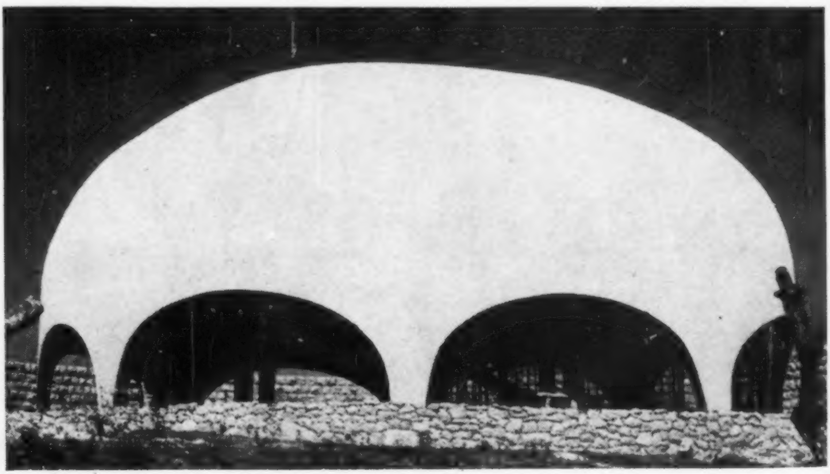


Fig. 1.

Fig. 3.—Concreting the Dome.

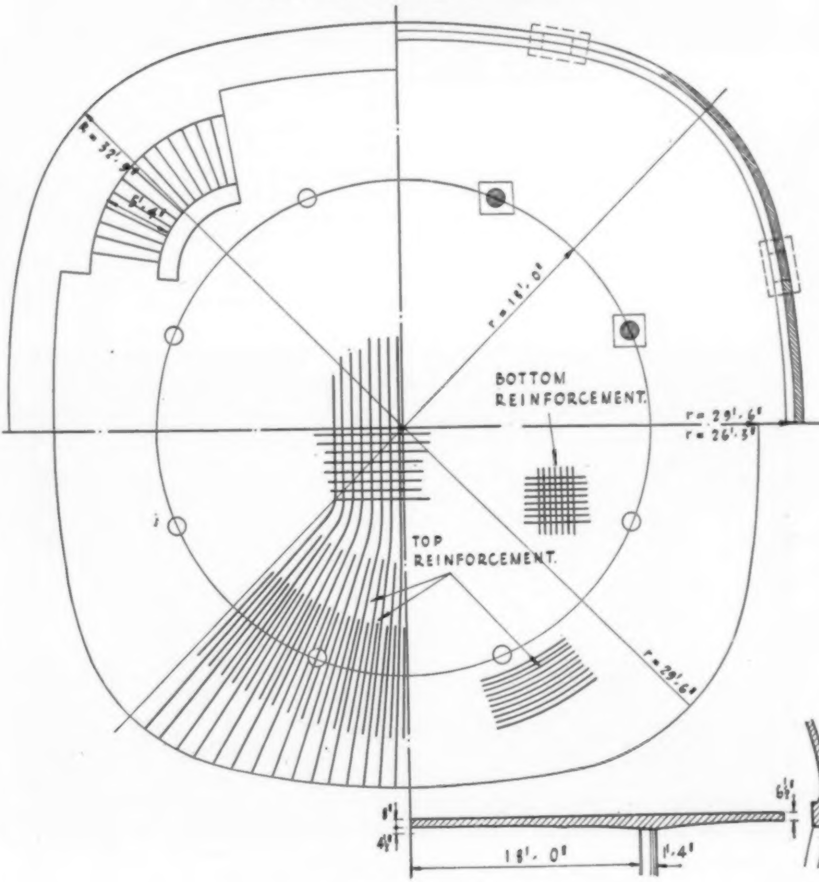


Fig. 4.—Plan.

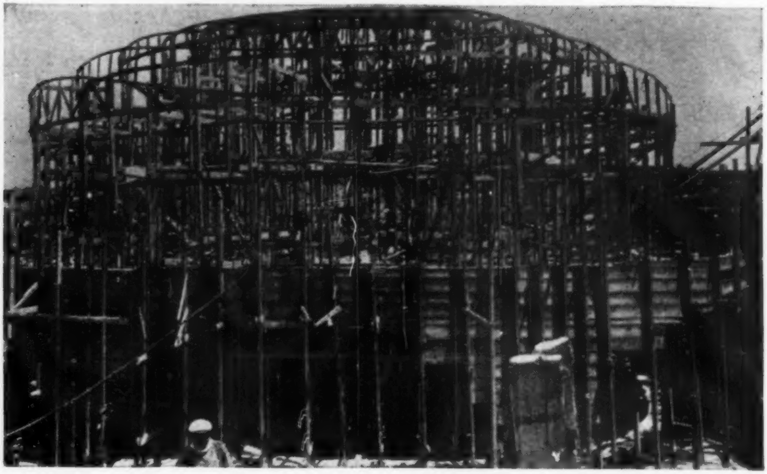


Fig. 5.—Supports for Shuttering.

Cremona's graphical method it was found that, in order to produce only direct stresses in the dome, the thickness of the base of the dome should be 2·5 times greater at points of minimum radius than at points of maximum radius.

Because of the variations in curvature, the design and erection of the shuttering presented difficulties. The supports for the shuttering are shown in *Fig.* 5; the shuttering took four weeks to erect, and the concrete was placed (*Fig.* 3) in four days. Most of the shutters were stripped after ten days.

The architects were Messrs. H. Rau and D. Resnik, in consultation with Mr. I. Olexinzer, M.I.Struct.E., who was the engineer for the structure.

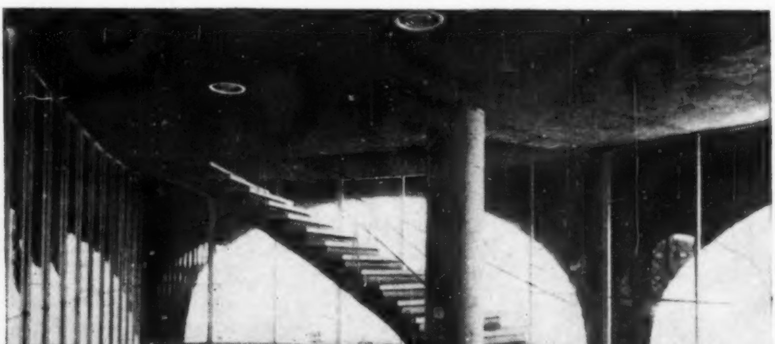


Fig. 6.—Interior View.

A Plea for the Education of Engineers.

[The following article is reprinted by permission from the Journal of the Engineers' Guild for July 1958. It emphasises and reiterates the views expressed in this journal for many years, and which are the subject of the Editorial Note in this number.]

Man's need for technology of increasing complexity is forcing the professional engineer into leadership. In Canada and the U.S.A. this trend is more evident than in Great Britain, where leadership has for so long been exercised principally by those educated in the traditional humanities. But even in Great Britain it is slowly being recognised that the best education available for engineering inculcates a discipline of mind and breadth of interest different from, but in no way inferior to, that to be obtained from reading history or philosophy.

Perhaps, therefore, this is an appropriate time to look afresh at Tredgold's inspiring definition, which although formulated in 1828 for civil engineering, remains valid for the many branches of engineering which have emerged since his day. Civil engineering, said Tredgold, "is the art of directing the great sources of power in Nature for the use and convenience of man". Until now, these great sources of power have been taken to mean the physical elements of the universe, other than man himself; and indeed it could be argued that it is this very concentration upon earth, air, and water which has led to the notorious ineptitude of so many engineers for high managerial responsibility. By excluding man from his studies, the engineer excludes the greatest of all sources of power, and therefore foregoes the right to exert leadership over his fellow-men.

This is not good enough. To translate technical advancement into social gain, technology must apply the findings of science to the needs of man and society. The engineer, unlike the scientist, is therefore closely concerned with humanity, and indeed carries a major responsibility for its continued comfort and welfare. But he has not as yet properly appreciated this role. His mental outlook has tended rather to divorce himself from human affairs, to shrink from dealing with irrational behaviour, and to leave to others the moulding of opinion and direction of emotion. Could he but be brought to accept the concept that Nature includes man as well as materials, and that his art should include the direction of emotional forces as well as physical forces, how much more effective he would be. Gone would be the dichotomy between technology and the humanities. Gone would be the frustration caused by non-technical authority. And gone would be the inefficiency of engineering management lacking psychological enlightenment.

What does this mean in practice? Is it realistic to confront young engineers with yet another range of subjects? Yes, it is: provided that it is done in the right way. Laudable efforts have already been made during recent years to attach a measure of the humanities to engineering curricula, and to encourage engineering graduates to undertake post-graduate study of such subjects as economics and law. Much has been done, too, through the engineering institutions and the technical press to discuss the problem and contribute to its solution. Yet much more remains to be done.

The mature engineer is well aware that changing circumstances are moving in his favour, but that the opportunity may be missed because of the shortcomings of his profession. The younger engineer is not. To him, the acquisition of letters designate to append to his applications for employment is both all-absorbing and sufficient. And, most regrettably, he is frequently scarcely aware that he is entering a leading profession with a great potential for enhanced public usefulness. It is to him that most attention should be directed. It is to him, as he qualifies in his thousands year by year, that two points should be emphasised ceaselessly. First, that as a member of a great profession, he must exercise loyalties and responsibilities to his profession in addition to those due to his employer. And secondly, he should soon start to prepare himself, by further study and practice, for administrative responsibility.

The great difficulty in offering non-engineering subjects for post-graduate

study has been that the student has seen little or no connection with those which really interest him and whose mastery will earn him his daily livelihood. Law, he may well decide, might be interesting, but much better to hurry from the examinations results notice-board to the appointments bureau and get fixed up in a job. Press on with engineering, he insists, and let the dilettantes linger to dally with these extraneous subjects.

Sir Eric Ashby * has indicated the escape from this dilemma. Press on if you must, he would say to the job-hungry graduate, but, as you work industriously at engineering, do try to widen your horizon of interest and knowledge by reading, discussing, and observing a widening area of cognate subjects. All this will become of great value to you, your profession, and the nation in ten or fifteen years' time; and it will remove the risk of being stigmatised a mere technologist.

Acceptance of this advice could lead a civil engineer, for example, along the following line of study. As a civil engineer, he will have a natural interest to read the biographies of the great engineers of the nineteenth century. The stories of Telford, the Stephensons, and Brunel make thrilling reading by any standard. Moreover, the engineering works for which these and many other engineers were responsible had a profound influence upon the pace of the Industrial Revolution.

New industries, new communications, new towns, population movements, financial crises, social distress—all these phenomena characterised Great Britain as it led the way into the technological era, and experienced the rapid transition from a static to a dynamic society. This is the stuff of economic history, and through it any engineer of enquiring mind can come to an understanding of the consequences which can flow from his creations. Within this same subject, furthermore, he will gain enlightenment on the emergence and growth of trade unionism, an invaluable increment of background knowledge for his later managerial responsibilities. And so his widening area of cognate subjects can expand from economic history to political history, from political history to political philosophy. Another route might be from an appreciation of the æsthetics of civil engineering structures to an interest in architecture, from architecture to sculpture, from sculpture to painting. There is no end either to the areas to be explored or to the enrichment of the personality which explores them.

But somewhere in the process, and fairly early at that, the road from one cognate subject to the next should offer a sojourn into the subject of management. For the highest levels of responsibility, a knowledge of the basic principles of management is essential. The professional manager is indispensable to big business; and there is a crying need for good engineers to be good business men. First contact with the literature on management can nevertheless be daunting, and initial zeal can quickly be dissipated unless supported by a wider concept. The reflective mind might find continuing stimulation from the question "what is the purpose of production?" Is it private gain or the satisfaction of human needs? Each individual must find his own answer, but whichever it may be, efficient management is essential for success; and administrative effectiveness combines economy of scarce resources with encouragement of human endeavour.

Professional engineers are, by definition, men of high educational attainment, with minds given to independent thought and critical appraisal. To develop their talents fully over a lifetime requires variety of experience and widening responsibilities. The fault so far has been to halt these responsibilities at the frontier with non-engineering functions. To continue to do so will incur the risk of reducing engineering from the status of a profession to that of a craft. The crossing of the frontier, not only willingly, but eagerly, will perhaps come more easily when seen as a natural extension of "directing the great sources of power in Nature for the use and convenience of man".

* President of Queen's University, Belfast. Chairman of the Scientific Grants Committee of the Department of Scientific and Industrial Research.

Book Reviews.

"Civil Engineering Construction." By J. M. Antill and P. W. S. Ryan. (London: Angus & Robertson, Ltd. Price 75*s*.)

WRITTEN by an Australian engineer and a lecturer at New South Wales University of Technology, this book is a survey of the machinery used in civil engineering works and of construction methods. It deals with plant and tools for timber work, compressed-air, excavation, rock-drilling, earth-moving, tunnelling, blasting, hoisting and conveying, pumping, dredging, pile-driving, diving, plant for preparing concrete aggregate, concrete mixing and placing, shuttering and scaffolding, riveting, welding, electrical plant, maintenance of plant, construction methods, prestressed concrete, bridges, roads, dams, marine works, pipelines, paints, underpinning and shoring, estimating, office work, labour management, and many other items that are encountered in building and civil engineering construction. The book is a useful general survey of the subject, but it is necessarily superficial in parts due to the attempt to deal with so much in one book. There is an extensive bibliography, mostly giving references to Australian publications.

"Materials and Methods of Architectural Construction." By H. Parker, C. H. Gay, and J. W. MacGuire. (London: Chapman & Hall, Ltd. Price 96*s*.)

IN this book of 710 pages the authors deal with the properties and uses of all the common building materials. The authors are professors at the University of Pennsylvania, and the book deals with U.S.A. practice. Some fifty pages are given to reinforced concrete. It is not obvious why the word architectural is used in the title of a book which follows the same general lines as other books on building construction.

"Proceedings of the Second Symposium on Concrete Shell Roof Construction." (Oslo: Teknisk Ukeblad. London: Claude Gill Books, Ltd. Price £5.)

THE subjects discussed are grouped in four sections, namely (1) Recent notable shell structures, (2) Trends in the design of shells, (3) Research on shells, and (4) Prestressed and precast shells. The volume comprises 370 pages, and includes thirty-five papers and reports of the discussions.

"Heat Transfer in Deep Underground Tunnels." (H.M.S.O. Price 3*s*.)

IN this Technical Building Study an account is given of an investigation made with the object of obtaining a formula relating to the rate of rise of temperature in deep underground tunnels.

Lectures on Building.

THE following lectures have been arranged by the Ministry of Works. Admission is free.

"New Traditional" Methods of Building, by R. C. Scholefield. Technical College, Connah's Quay. November 13. 7 p.m.

The Builder and his Contract, by Norman P. Greig. College of Further Education, Luton. November 13. 7.30 p.m.

Practical Formwork Design and Construction for Concrete, by J. G. Richardson. College of Technology, Portsmouth. November 13. 7.15 p.m.

The Thermal Insulation of Buildings, by N. Foster. Technical College, Carlisle. November 18. 7.15 p.m. And Technical College, Workington. November 19. 7 p.m.

The R.I.B.A. Form of Contract, by I. N. Duncan Wallace. Technical College, St. Leonards-on-Sea. November 18. 7.15 p.m.

Recent Concrete Construction in Scotland, by Peter Russell. The Museum, Kirkcaldy. November 20. 7.15 p.m.

Problems of Plastering and Rendering by E. L. Westbrook. Technical College Southampton. November 20. 7.30 p.m.

Weathering and Deterioration of Renderings, by C. Hobbs. Technical College, Watford. November 20. 7.30 p.m.

Soil Mechanics in the Building Industry, by D. I. Harris. S.E. London Technical College, London, S.E.26. November 24. 7 p.m.

Flats and their Costs, by T. L. Knight. Ministry of Works, Five Ways House, Islington Row, Birmingham. November 25. 7.15 p.m.

Metals in Building, by R. D. Tarleton. Medway College, Chatham. November 25. 7.15 p.m.

Operational Research and Building Management, by J. C. Weston, T. V. Prosser, and C. A. Francis. Building Centre, London, W.C.1. November 25. 6.30 p.m.

Structural Properties of Lightweight Concrete, by G. Newton. Technical College, Stafford. November 27. 7.15 p.m.

FIFTY YEARS AGO.

From "CONCRETE AND CONSTRUCTIONAL ENGINEERING," NOVEMBER–DECEMBER, 1908.*

THE ROLL MIXER.—This is a machine of the batch type which has only recently been introduced into England. Its chief peculiarity is in the nature of the mixing drum; this is a vessel formed of cup-shaped halves fixed upon a spindle in such a manner as to permit the halves being drawn apart to discharge the concrete, and closed together again to receive the fresh charge. This vessel revolves about 12 times per minute; it is supported at one side by the central spindle, and at the other by friction rollers under the rim of a central opening, through which the materials are fed. The drum is made of two castings, to one of which is bolted a sleeve carrying a worm; this worm serves to move one half of the drum along its spindle when it is required to discharge. . . . A detailed statement is given in the maker's catalogue showing the cost of running a machine of 12 cub. ft. drum capacity, and 15 cub. yd. output per hour, for a period of 1600 hours or half a year. In this it is stated that the cost per yard cube of concrete worked out at 4·13 pence; this was inclusive of power, labour (six men), bringing machine to and from yard, interest on cost, and repairs and depreciation. [In 1908 most mixers were continuous and driven by steam. The batch mixer was a recent innovation.]

THE LONDON BUILDING ACT.—The Building Act Committee recommend that application be made to Parliament in the Session of 1909 with a view to the amendment of the London Building Act, 1894, so as to facilitate the use of steel or reinforced concrete in the construction of buildings and to make any necessary provision with regard thereto.

* "Concrete and Constructional Engineering" appeared in alternate months until September, 1909.

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